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IMPROVEMENT OF SACRIFICIAL ANODE CHARACTERISTICS OF Al-Mg-Zn Alloy MATERIAL

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ABSTRACT

The paper is aimed at improving the sacrificial anode characteristics of Al-Mg-Zn alloy for use in marine applications. The researches have shown that using Aluminum alloy Al-Mg-Zn as sacrificial anode can reduce the corrosion rate. This paper deals with study of effect of various compositions and heat treatments on the sacrificial anode efficiency of the alloy. In this work the alloy Al-Mg-Zn is manufactured with varying compositions, and then they are subjected to heat treatment for different time periods. Then these samples are tested and the efficiency is calculated. The results obtained are studied and the most efficient sample is determined.

KEYWORDS: Al-Mg-Zn alloy, Sacrificial anode, cathodic protection system, effect of Tin, anodic efficiency.

INTRODUCTION:

Corrosion of the pipelines is a major problem while carrying oil under the sea. Several techniques abound for checking the problem of corrosion. Cathodic protection (C.P.) is one of the several techniques that are employed in many industries and marine environments to control corrosion. In this regard sacrificial anode cathodic protection is greatly employed to protect oil pipelines, marine and some domestic structures. With this system, electric current is applied by the employment of dissimilar metals with the driving voltage being created by the potential generated between the two metals in the electrolyte. The electrochemical behavior of sacrificial anode materials is of vital importance for the reliability and efficiency of cathodic protection systems for seawater exposed structures.

MATERIALS AND METHODS:

Aluminum and its alloys were used in fabrications because of their low weight, good corrosion resistance and weldability. Al-Mg-Zn (7xxx) alloy are Aluminium alloys having high strength, light weight and relatively low tendency for over ageing. Generally, Aluminum Zinc, and Magnesium are the metals mostly employed for sacrificial cathodic protection of metals. It is affirmed that aluminum are the preferred sacrificial anodes for controlling and preventing corrosion in marine environments. The actual limit in the use of magnesium based sacrificial anodes is their relatively low efficiency which gives rise to the loss of substantial parts of the required current capacity.

To study the actual variation of properties of the alloy with composition, each casting is done with a different set of composition and the variation of property is studied based on these. The selection of composition range is based on the properties and behavior of each element depending on its composition and matching those to the required properties.

Thus the metals are mixed in the required proportion. The composition of the cast alloys are tested in with mass spectrometer which would tell the details about percentage of metal in each alloy.

The various compositions are designated as samples. The first three samples only have variation in their Zn content mainly. For the fourth sample a very small quantity of Tin is added to see its effect. In the sample5 and 6 the tin content are increased to 1 and 2% respectively to find their effect on the sacrificial anode efficiency of the alloy.

Casting this alloy is done using die casting method. The melting temperature of the alloy is around 680-700°C. The whole melting process is done in a muffle furnace which is an electrical furnace. The total capacity of the furnace is to hold a crucible whose capacity would be 700g. The required quantity of the metals is weighed using a weighing machine with accuracy of 0.001g. The metal mold and the weighed metal are kept in a hot air oven for preheating to remove the moisture content.

The crucible is placed in the muffle furnace for pre heating. The temperature of the furnace is set to 700°C. Once the furnace temperature reaches 600°C the metals are charged into the crucible. The metal will melt at 700°C. Once the metals melt it is taken out and the slag is removed from it.

After that the mold is assembled and the molten metal is poured into it. While pouring the time is calculated and the pouring is done in such a way that a uniform feed is acquired throughout the volume of the die cavity. After pouring the molten metal is allowed to solidify and knock out is done to separate the metal from the die.

The heat treatment of this alloy is carried out in two different ageing times after cutting the specimen into required no of pieces. First this alloy is heated to its solid solution temperature mentioned in the A.S.T.M and the suitable temperature range is selected.

The cast piece is heat treated in muffle furnace and then the temperature is reduced by sudden cooling. Then the actual age hardening process is done as per A.S.T.M standards. The aging time is 8 hrs and 16 hrs. And now the mechanical properties have to be determined with the change in aging time. The heat treatment process is carried out in a muffle furnace in a controlled manner.

The samples are heated to this temperature and one set of samples are removed after 8 hours and the other set after 16 hours. Rapid quenching is done (Water quenching) and the temperature of the water should not exceed 38°C. There were totally 18 specimens of six different compositions and three different aging times.

The specimens of different compositions were cast and subjected to heat treatment. The specimens were then cut to size of 50x10x10mm and machined to get very good surface finish. The mild steel blocks of size 50x75x10 mm were taken and grinded for good surface finish. The specimens and mild steel blocks were then washed, degreased in acetone and dried. Holes were drilled in each sample for the purpose of suspending in the electrolyte. The electrolyte for the experiment is sea water. The sea water were collected and stored for the experiment.

The specimens were washed in acetone and dried. The specimens were then weighed for the initial mass in weighing machine with accuracy of 0.001g. The connecting wires are then inserted into the holes provided for suspension. The samples are connected to the mild steel blocks. Figure 3.2 shows the basic setup used for the testing. The anode and the mild steel block are then immersed in the sea water as shown in the figure. The ammeter with mA rating is connected to the setup as shown in the figure.

The setup is kept undisturbed for two days. After two days the current values as shown in the ammeter are noted down. The alloys are removed and the corrosion products formed on the surface of alloy are removed by scrubbing under running water using a fine scrubber. Then the alloys are cleaned using acetone and dried and the weight of the alloy is taken.

The mass lost is found out and tabulated the same procedure is repeated every two days for 10 days and all the current values and mass lost are tabulated.
The efficiency of anode is thus given as:

$$E(\%) = \frac{CC_A}{CC_{TH}} \times 100$$

Where E is the anode efficiency CC_A and CC_{TH} are respectively the current capacity of the actual and theoretical anode. The CC_{TH} for aluminium alloys are 2500A-hr/Kg.

The actual current capacity CC_A is the ratio of the product of current produced in the system and the time of exposure to the mass lost during this time. The more the current produced the better the CC value is, similarly lesser the material lost better will be CC value. CC was calculated using the formula:

$$CC = \frac{It}{(m_i - m_f)} \times 100$$

Where I is the current produced in A, and m_i and m_f are the initial and final weight of the alloy in grams and t is the time in hours. The current value is obtained from the ammeter. The m_i value is obtained from the weighing machine and m_f is the value taken using weighing machine after every two days.

RESULTS:

The current and mass lost value obtained during the testing of the anode is tabulated in table 1. This current is produced due to the flow of electrons from the Al-Mg-Zn alloy to the mild steel sample to replenish the electrons lost from the mild steel due to corrosion.

Table 1

No: of days	Sample 1						Sample 2					
	Mass lost (g)			Current (mA)			Mass lost (g)			Current (mA)		
	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age
2	0.029	0.002	0.019	12	1	5.5	0.035	0.012	0.024	13	5	7
4	0.03	0.012	0.022	6.5	2.5	3.5	0.036	0.014	0.031	7	3	3
6	0.079	0.012	0.025	10.5	1.7	2.5	0.083	0.027	0.044	10	3.7	5
8	0.083	0.024	0.05	8	2.5	3	0.107	0.054	0.055	9	5	5
10	0.117	0.032	0.058	8.5	2.5	2.5	0.153	0.065	0.056	11	5	2.5

No: of days	Sample 3						Sample 4					
	Mass lost (g)			Current (mA)			Mass lost (g)			Current (mA)		
	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age
2	0.043	0.01	0.017	15	4	5.5	0.004	0.011	0.011	1.5	7.2	8.9
4	0.044	0.012	0.021	9	2.5	3.5	0.013	0.034	0.014	2	11.8	5.5
6	0.094	0.032	0.064	11	5	5	0.033	0.054	0.026	8.1	12.2	7.5
8	0.104	0.063	0.069	10	6	5.5	0.054	0.084	0.054	10.3	15.2	10.9
10	0.118	0.076	0.088	9	6	6	0.06	0.093	0.066	9	13	11

No: of days	Sample 5						Sample 6					
	Mass lost (g)			Current (mA)			Mass lost (g)			Current (mA)		
	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age	As cast	8 hrs aged	16 hrs age
2	0.002	0.002	0.017	2	1.8	13	0.011	0.004	0.018	9.8	3.8	14
4	0.01	0.012	0.021	4.3	5.5	8.3	0.034	0.014	0.022	15.8	6.3	9
6	0.032	0.012	0.063	9.3	4	17.9	0.054	0.033	0.024	16.8	10.8	6.4
8	0.076	0.023	0.068	16.9	5.5	14.2	0.084	0.053	0.052	20	12.2	10.6
10	0.09	0.033	0.088	15.3	7.5	14	0.106	0.062	0.057	20.3	11.6	9.3

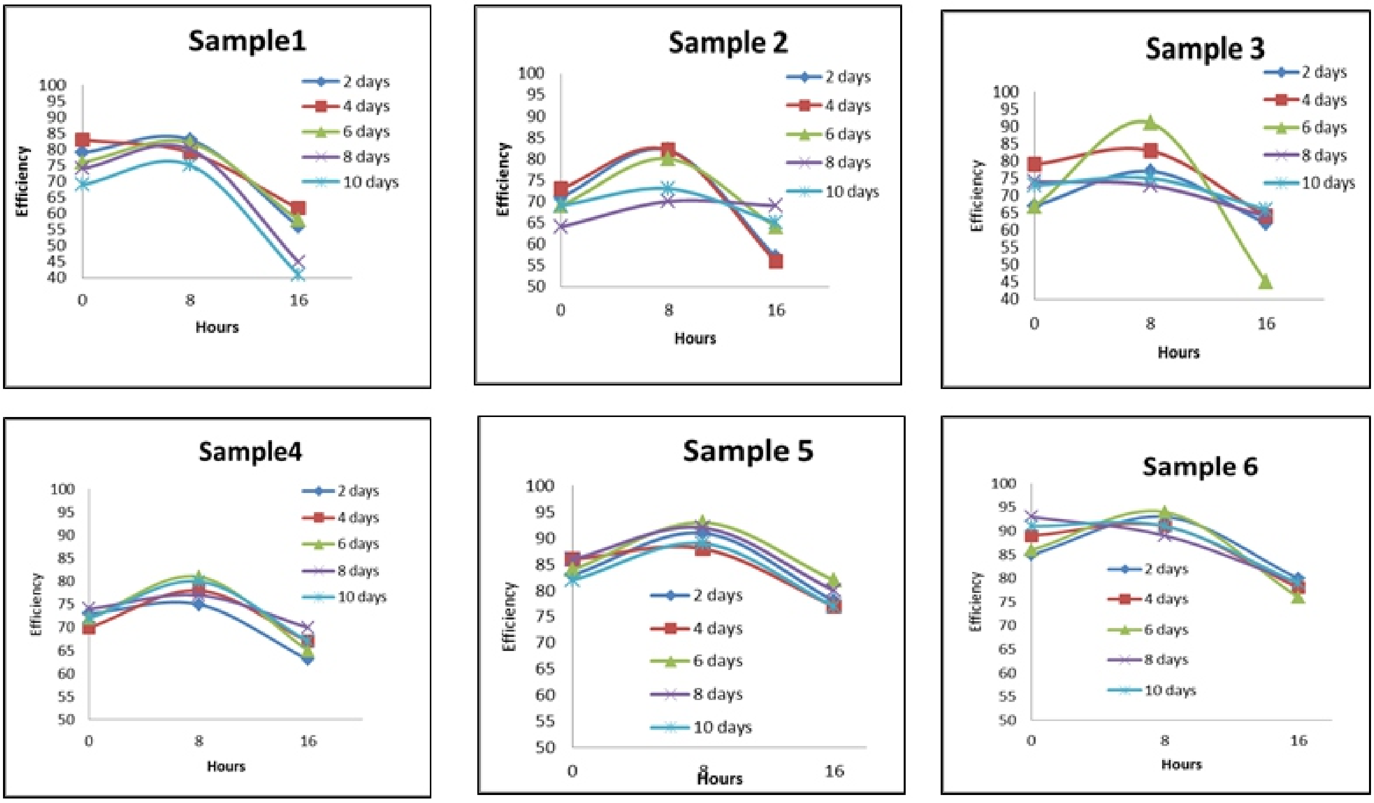

Figure 1 Efficiency Vs. Ageing for all six samples

This replenishing of the electrons lead to the protection of the mild steel from corroding away. The mass lost from the anode is due to giving away of the electrons from the anode to the cathode. The mass lost need to be minimum for obtaining maximum efficiency. If mass lost is too high then the sacrificial anode will have to be changes after very short period of time which is not economical. Thus it is important that the mass lost has to be very minimum for a good sacrificial anode.

The efficiency obtained for different composition at different heat treatments for different days is tabulated. To know the variation of the efficiency with the change of composition and heat treatments, graphs has been plotted for Efficiency Vs. Heat treatment and Efficiency Vs. Sample.

DISCUSSION:

From the results obtained from the testing of the samples it was found that anode

efficiency does not show much considerable change due to increasing of the amount of Zn in the alloy. Then the Tin content in the alloy is increased the efficiency of the anode is found to have increased to a maximum of 93%. When heat treatment is done it was found that when the samples are heat treated for 8 hours the efficiency increases considerably, but on further heat treatment for 16 hours the efficiency value decreases.

CONCLUSIONS:

Thus we conclude that the sample having maximum tin content, when heat treated 8 hours will give the maximum efficiency of 94% and give maximum corrosion protection when used under sea.

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